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DEMYSTIFYING COMMUNICATION SIGNAL LOST FOR NETWORK REDUNDANCY CONNECTIVITY: EVIDENCE FROM COVERAGE ANALYSIS STUDIES ON AMR SYSTEMARTICLE

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ABSTRACT

These studies report on the communication signal lost factors that were analyzed and supported by evidences on coverage analysis activities for Automatic Meter Reading (AMR) systems. We have categorized the influential signal lost factors into four core elements that were concluded based on our field measurement studies. We have conducted measurement on Received Signal Strength Indicator (RSSI) parameter and outline the steps and techniques of such research activity. Our results show that a single network connection might not be able to support for reliable Internet network connectivity for critical communication device like AMR system. Hence, applying network redundancy technique into developing a more functional ... ignal lost for AMR meters.

Keywords: Signal strength; AMR; Cognitive Network Selection; Network redundancy; Signal lost.

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1. INTRODUCTION

In today's business operations, reliable network connectivity is a must in order to continuously access corporate resources, business data, vendors' information and billing details all the times [1]. As an example, utility company with smart grid technology introduces a real competitive advantage whereby, connected devices can provide the company with up-to-date information about electric, gas and water consumption so that it helps to identify patterns and trends. The company can better manage their infrastructure, assets and operations with comprehensive data analysis [2]. Bad connectivity can also influence customer satisfaction. A report by [3] highlighted several complaints from utility customers who were having lost connectivity on the meter and it took a month to solve the issue despite nationally, a network coverage test was conducted. Obviously, the issue could be due to single network connectivity that the meter has or the location of the meter was down in the basement [4]. It is important to realize that, Internet connection to these key devices in the utility network that capture such data should be 99.99% available all the times.

How can we create such highly available connectivity? A concept known as network redundancy can be applied to support such capability. Redundancy attempts to eliminate any single point of failure on the network [5]. The goal is to duplicate any required component whose failure could disable critical applications. The component could be a core router, a switcher and so on. Though redundant network can be an alternative solution to the discussed issue, we need to know which network exists at that particular meter location for multiple networks modem to choose effectively. This solution does not need to be applied to all meters but perhaps only selected locations which are critical in network connectivity. Such concept was once enhanced and investigated by [6] [7] whereby, the work mostly focuses on intelligent algorithm on switching from one network to the other based on reliable parameter such as data throughput, in contrast to the conventional parameter such as RSSI. Hashim et al has coined the term 'cognitive network selection' concept as illustrated by Fig. 1.

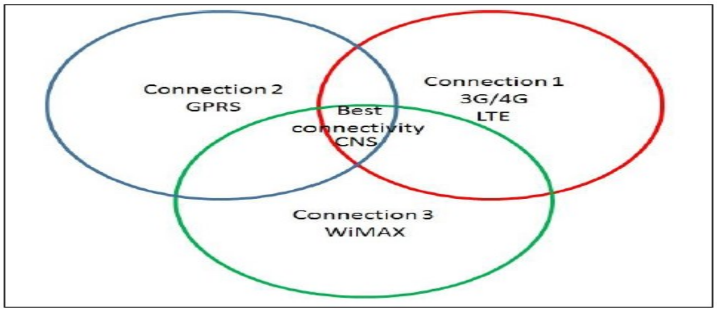

Fig.1. Cognitive Network Selection concept [6]

AMR on the other hand, enables a utility company to obtain readings without physically be near the meter [8]. Methods include transmitting a meter signal through cellular network such as GSM/GPRS. Fig. 2 illustrates the system architecture of AMR using cellular network. The energy meter equips with built-in communication module through GSM modem. To date, AMR meters are using modem that is having only one network connectivity. Although AMR system gives the ease and fewer impediments in gathering meter readings in remote locations, a report from utility billing center, that indicates, data sometimes missing due to unavailability of cellular connectivity, motivates us to study the issues in greater depth.

Fig.2. AMR system architecture [9]

In order to measure basic network availability, a common parameter such as RSSI can be utilized for detecting any network coverage. RSSI describes the total signal power received in miliwatts (mW) whereby the value is usually expressed in dBm (logarithmic scale) and typical values are -100dBm for a low signal level to -60dBm for a very strong signal level [10]. The primary goal of measuring RSSI parameter is basically to estimate distance which indirectly reflects the proximity range between two nodes. At a certain position, the value indicates whether the signal power is strong or weak. Strong signals usually show the distance from the transmitter to the receiver, is within a short range and vice versa. This is depicted in Fig. 3.

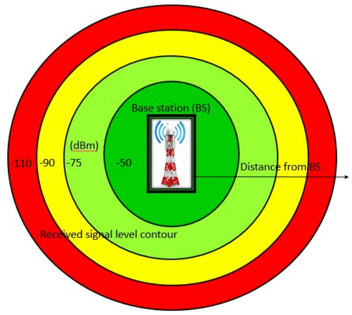

Fig.3. RSSI level contour

In this paper, we will describe the issues of network connection signaling lost as experienced by AMR system followed by our field measurement studies that provide evidences to these issues based on signal strength measurement performance. The results are then discussed and form a basis to the enhancement of network redundancy concept as our future research work. Finally, summary of the studies as well as acknowledgement remark are highlighted towards the end of this paper.

1.1 Network connectivity signaling lost

Fig. 4 illustrates key factors that are identified as elements that mostly influence signal lost. Network coverage known to be one of the main issues that cause major signal lost. Local Internet service providers may provide infrastructure based on population demand on certain network technology. As an example, when most customers are on 3G/4G network due to high data rate capability, the legacy system that are still camping on 2G network such as AMR and vendor machine will suffer from this and slowly operator will no longer maintain such network. Existing system that transmits less than 200 Kbytes data prefers low frequency transmission rate such as GSM. Network coverage is also pretty much related to the physical location of the meter itself. Outdoor meter that is surrounded by buildings will experience blocking signal should the base stations located outside the surrounding areas. Another issue is when the meter resides at the basement down below several floors. Other than that, a remote area where mostly private residential resort located far from hustle and bustle of the city is also away from any main network coverage.

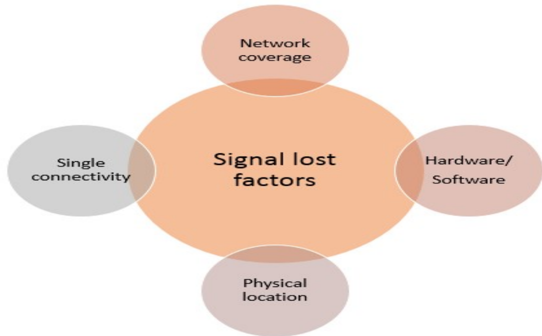

Fig.4. Signaling lost key factors

Single network connectivity on the vendor modem is also another interrelated factor to the signal lost issue. Signal strength fluctuation of single network at the modem Internet connection can be due to surrounding interference. Instability of the signal causes non-uniform data transmission rate. Hardware and software issues are the least occurrence in AMR except for several cases of legacy meter that was originally installed without any wireless communication capability. Fig. 5 shows several under studied locations of the AMR meters.

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Fig.5. AMR locations

1.2 Signal strength field measurements

Having discussed the signal lost factors; we have conducted a signal strength measurement to the identified AMR locations that were reported having difficulties in obtaining data wirelessly. It was lodged that most of the places do not have sufficient network coverage so further analysis and assessment need to be done. The signal strength measurement was conducted using the following steps.

1. Identify spectrum arrangement plan as advertise by regulator. For our study, we refer to Malaysian Communication and Multimedia Commission (MCMC) frequency assignment to each operator.
2. For each operator, follow the frequency allocation based on the spectrum plan.
3. If we are looking at the RSSI parameter, follow the downlink frequency based on each air interface technology. For GSM (2G) we refer to frequency 900 MHz and 1800 MHz, UMTS (3G) 2100 MHz and LTE (4G) 2600 MHz.
4. Tune the spectrum analyzer into specific frequency range of interest for each operator. In this study we select Celcom, Maxis and DiGi as the operators since they are the main cellular network operators in Malaysia that have wider network coverage nationwide.
5. Measure the signal strength in dBm as well as the spectrum power density.
6. Save and record the value.
7. Repeat step 2-6 for other air interface technology on another operator.

Fig. 6 depicts the frequency arrangement for Malaysian operators classified into separate air interface technologies.

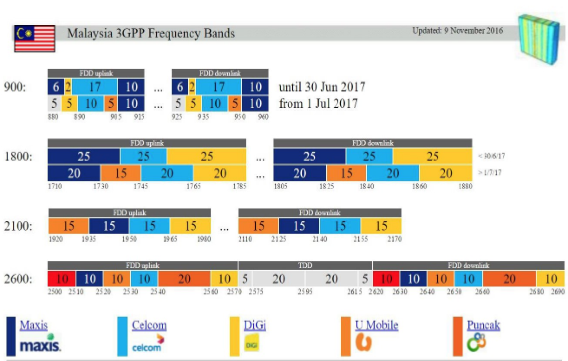

Fig.6. Malaysian 3GPP Frequency Bands for local network operators

For downlink frequencies of reference, Table 1 tabulates the frequencies in details.

Table 1. Downlink frequencies arrangement

	Bands	Maxis	Celcom	DiGi
2G	900	925-931	933-950	931-933
	1800	1805-1830	1830-1855	1855-1880
3G	2100	2125-2140	2140-2155	2155-2170
4G	2600	2630-2640	2650-2660	2680-2690

Selected locations are identified as follows based on their unique environment categories on the signal lost effects.

- Remote area – Kg. Jenderam Hulu, Dengkil, Selangor.
- Surrounding buildings – Shaftesbury Square, Cyberjaya, Selangor
- Hill side – Diplomatic Enclave, Putrajaya, Selangor

A portable spectrum analyser was used as a measurement tool for our signal strength analysis. This is shown by Fig. 7.

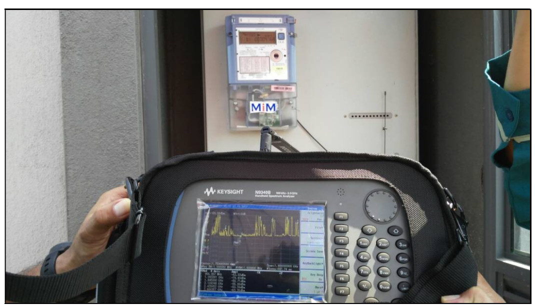

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Fig.7. Portable spectrum analyser

2.0 RESULTS AND DISCUSSION

In this section, we are going to show the results for each measurement conducted at the selected sites under studies.

Remote area: Kg. Jenderam Hulu, Dengkil

Table 2. Signal strength (dBm) result Kg. Jenderam Hulu

	Frequency bands	Maxis	Celcom	DiGi
2G	900	-86.84	-68.35	-90.03
	1800	-71.71	-77.80	-77.55
3G	2100	-76.79	-81.89	-76.95
4G	2600	-88.11	-83.63	-107.85

Table 2 shows the measured values for signal strength results in dBm. It is observed that Celcom provides better signal strength for GSM900 and for GSM1800 whereby the other two operators are giving almost similar results. For 3G technology, Maxis and DiGi show better result than Celcom by just 5dBm different. For 4G LTE, DiGi signal strength was having result below -100dBm.

Surrounding buildings: Shaftesbury Square, Cyberjaya

Table 3. Signal strength (dBm) results for Shaftesbury Square

	Frequency bands	Maxis	Celcom	DiGi
2G	900	-101.19	-86.41	-102.07
	1800	-86.41	-87.04	-77.95
3G	2100	-87.04	-94.26	-85.72
4G	2600	-94.26	-86.41	-101.38

For Shaftesbury Square, the surrounding building effects on the meter mostly results into below good quality signal. Maxis for example shows results ranging from -86dBm to -101dBm. For an AMR system that is using 2G technology, it is a concerned that at specific locations, the above result will influence what network should we subscribe and the hardware compatibility on the chosen GSM900 or GSM1800.

Hill side: Diplomatic Enclave, Putrajaya

Table 4. Signal strength (dBm) results for Diplomatic Enclave

	Frequency bands	Maxis	Celcom	DiGi
2G	900	-114.55	-88.70	-94.48
	1800	-90.25	-93.54	-85.69
3G	2100	-90.55	-77.78	-83.04
4G	2600	-99.33	-100.29	-103.83

The results at Diplomatic Enclave shows quite a poor result on most technologies despite Putrajaya location is among the main cities in Kuala Lumpur. Diplomatic Enclave is an open land space which is yet to develop. It is suspected that the AMR meter is communicating with the base station that is situated miles away where population is denser. This could result into such signal strength measurement performance. Readings in Table 4 can be further represented in the following graph shown by Fig. 8.

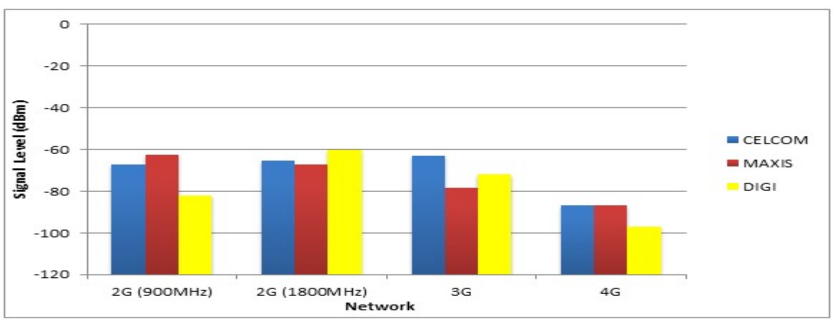

Fig.8. Diplomatic Enclave signal strength comparison analysis

Based on the graph, it can be concluded that Maxis offers stronger signal strength with more than 4.6 dBm higher than other service providers for 2G network at 900 MHz frequency range. For 1800 MHz, DiGi offers better signal strength with more than 4.95 dBm higher than other service providers. For 3G network, Celcom shows reliable signal strength with more than 8.96 dBm higher than the rest. For 4G network, Celcom offers reliable signal strength with just 0.28 dBm higher than other service providers.

2.1 Interpreting spectrum analyzer results

Perhaps, the primary results from spectrum analyzer measurement can tell something important about the network performance of an operator. The following Fig. 9, Fig. 10 and Fig. 11 illustrates the raw results of our measurements as inputs to the above-discussed tables specifically the channel performance for 3G networks since this this is the most popular networks to most customers. Perhaps this result can be the basis for utility company to further study on migrating the existing metering devices into 3G networks. The following results are samples from measurement values taken at Kg. Jenderam Hulu, Dengkil, Selangor. From Fig. 9, signal power shows some strength for the 2nd and 3rd channels of every 5MHz bandwidth but not the first 5MHz channel. With reference to Fig. 6, operator in Malaysia is being given with 15MHz bandwidth and this is divided into three separates channel of 5MHz each. In this result of Fig. 9, two channels are shown some good signal strength values. It can be interpreted that there could be two Celcom base stations operating at frequency 2145-2150MHz and 2150-2155MHz. The reason for the first bandwidth channel not giving any good signal strength could be due to the distance of the base station is far away from our AMR meter.

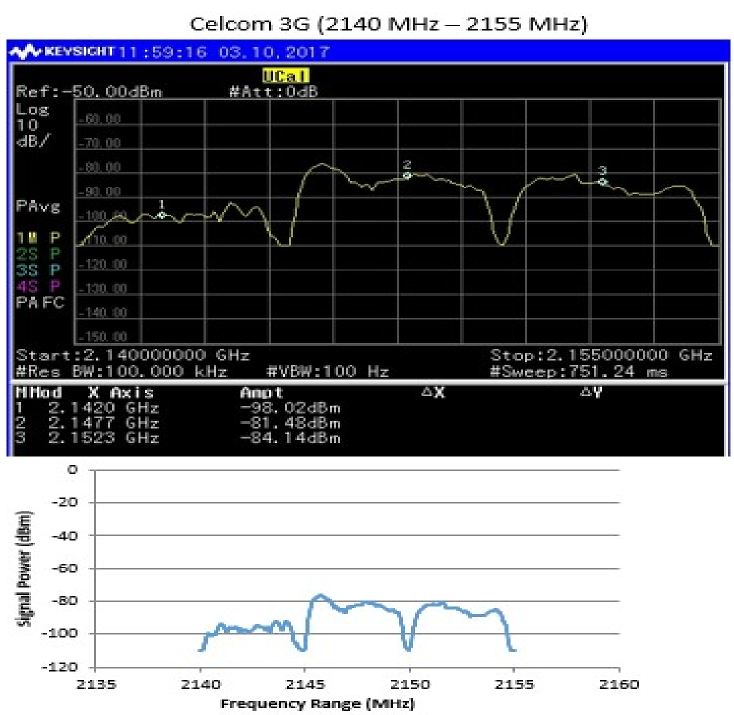

Fig.9. Celcom 3G networks at Kg. Jenderam Hulu

Fig. 10 on the other hand, shows a unique result whereby all threes allocated channels gives same power envelope values which can be assumed that those frequencies are all in operation by Maxis at Kg. Jenderam Hulu. The low results again could be due to the distance between the AMR meters to the nearest Maxis base stations. Similar performance is also obtained by DiGi and the only difference is the signal strength is a little bit better as compared to Celcom and Maxis (Fig. 11). Another unique example of flat signal strength performance is depicted by Fig. 12. This is the result of Celcom 4G signal strength measurements at similar location, whereby the signal from 2.MHz to 2.620MHz is almost flat showing there could be no base station operating at such channel frequency.

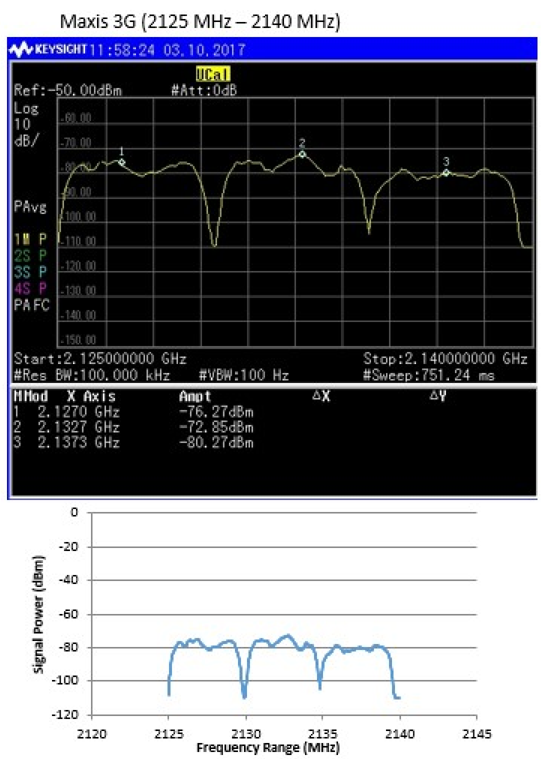

Fig.10. Maxis 3G networks at Kg. Jenderam Hulu

2.2 Network redundancy concept

Having discussed the above-mentioned analysis, there is a reason why having redundant network is important to AMR system which experiencing critical communications. By means of critical communications, the AMR meter cannot afford to experience any data lost and for our studies the number of times the data will be transmitted from AMR meter to data center or billing system is only twice a day. Our proposed system for future prototype development will be based on communication device module that is capable of shifting from one network to another network based on the data transmission demand and network performance behavior at that particular time of transmission. Following our previous research, a proposed module is illustrated in Fig. 13.

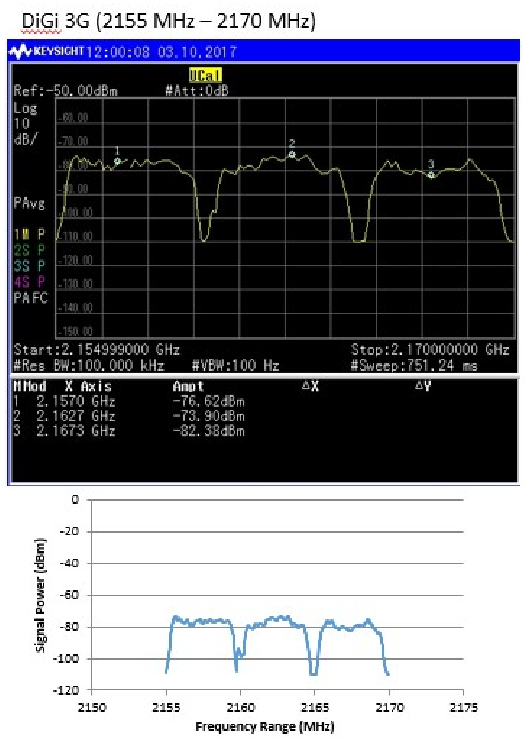

Fig.11. DiGi 3G networks at Kg. Jenderam Hulu

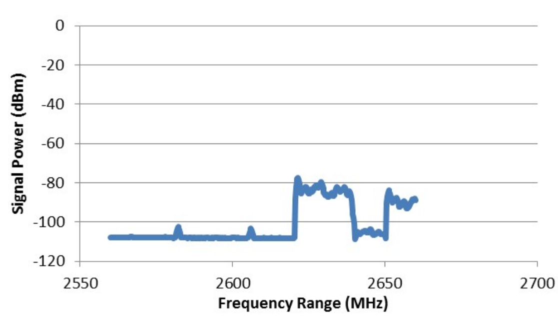

Fig.12. Celcom 4G signal strength performance at Kg. Jenderam Hulu

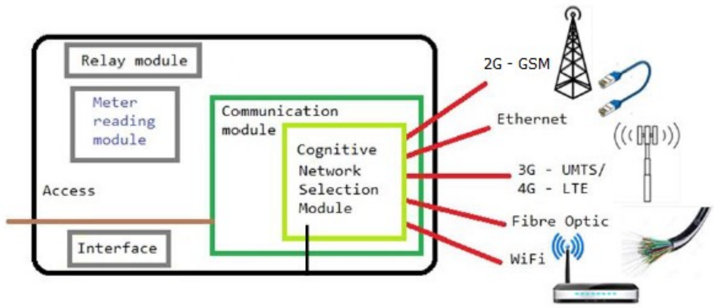

Fig.13. Proposed network redundancy communication module [6]

CONCLUSION

This research study has demystified the actual factors of communication signal lost based on field measurement studies on AMR system that was reported experiencing such challenges. We have categorized the influential four factors and discussed our technique of measuring signal strength performance using spectrum analyzer tool. We also shared our analysis results and possible causes that can be interpreted into understanding of the location of the meter, surrounding environments, infrastructure arrangement and demographic factor such as less population areas. From these studies we strongly believe that, a network redundancy communication module is needed for critical device such as AMR meter to have. We also foresee that such requirement will be very useful for other utility network such as smart meter and SCADA system.

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